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Meckel's Diverticulum in Infants and Children

WELLINGTON HUNG, M.D.*

INTRODUCTION

The diverticular outpouching of the small intestine which we refer to as Meckel's diverticulum was first mentioned in the medical literature, according to Lichtenstein,[1] by Heldanus in 1598. It was not until 1809, however, that Johann Friedrich Meckel[2] first recognized its derivation from incomplete obliteration of the omphalomesenteric duct.

The generally accepted incidence of this congenital anomaly in the general population varies from 1 to 3 per cent. Christie[3] reported a 1.1 per cent incidence in 5,768 consecutive autopsies at the New York Babies Hospital, and Kiesewetter[4] reported a 1.3 per cent incidence in 1,809 autopsies at the Children's Hospital of Pittsburgh. Meckel's diverticulum has been claimed by some to be the commonest anomaly of the gastrointestinal tract.[5]

It is well known that this anomaly may give rise to serious complications which occur predominantly in the first and second decades of life.[6, 7] In Soderlund's series of 115 cases of Meckel's diverticulum in children,[8] pathological complications were found in 47 per cent of the cases, while Brookes[9] reported complications to be present in 37 of 43 children in his series.

Embryology

Between the second and fourth week of fetal life, the yolk sac is joined to the primitive midgut by the omphalomesenteric duct. Through this duct the embryo receives nourishment from the yolk sac. At approximately the seventh week of fetal life the omphalomesenteric duct begins to supply the nutritional needs of the fetus.[10] The duct normally becomes a fibrous cord extending from the umbilicus to the bowel and is later absorbed. It usually disappears by the fifth or sixth month of fetal life.

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Pathological Anatomy

Incomplete obliteration of the omphalomesenteric duct at any point along its course leads to a variety of anomalies.

When the omphalomesenteric duct remains patent the entire distance from the intestine to the umbilicus an omphalomesenteric fistula is present. In such a case, red glistening mucous membrane is seen at the umbilicus. This fistula must be differentiated from a patent urachus.

The entire omphalomesenteric duct may close but its distal connection to the umbilicus remains present. This may form an opening through which a loop of bowel may herniate.

If only the umbilical portion of the duct persists it may form an umbilical polyp or cyst and be lined with intestinal epithelium.

Both ends of the duct may close but the midportion remains patent with formation of a large mucus-containing cyst. This is referred to as an omphalomesenteric cyst.

Persistence of the intestinal part of the duct produces the most common of the omphalomesenteric duct anomalies, a Meckel's diverticulum.[11] Meckel's diverticulum occurs most frequently on the antimesenteric border of the ileum within 90 cm. proximal to the ileocecal valve.[3, 6] The diverticulum varies in length from one to several centimeters; the distal end usually lies free in the peritoneal cavity.

Christie[3] has pointed out that this anomaly is often associated with other congenital abnormalities, and has suggested that a primary defect in the germ plasm is a possible etiological factor in the persistence of part or all of the omphalomesenteric duct.

Pathology

The wall of the Meckel's diverticulum is composed of the seromuscular layers of the small intestine. In addition to the normal ileal mucosa, the diverticulum may contain heterotopic gastric, pancreatic, duodenal, biliary tract, or colonic tissue.[9] Twenty-five per cent of all Meckel's diverticula contain heterotopic tissue, most often gastric tissue.[10] Curd[14] has demonstrated that the heterotopic tissue never extends beyond the diverticulum into the ileum. The gastric tissue is capable of secreting hydrochloric acid and pepsin.[12, 13] Greenblatt and his associates[15] have shown that the secretion usually begins synchronously with gastric activity. Thus, the mucosa in the diverticulum is exposed to these digestive juices at a time when food and intestinal juice are not present to act as buffers. Matthews and Dragstedt[16] have shown that the mucosa of the intestine becomes progressively more sensitive to the irritating propertis of hydrochloric acid and pepsin as the distance from the stomach increases. The pathological changes produced by the heterotopic gastric tissue resemble the changes seen in peptic ulceration of the stomach and duodenum. This peptic ulceration may lead to per-

foration. Ulceration may occur in any of the tissues in the diverticulum, but the most frequent site is the intestinal mucosa adjacent to the boundary of the heterotopic mucosa.

Four theories advanced to explain the presence of the heterotopic tissue in Meckel's diverticula have been listed by Greenblatt et al.[15]: a) Albrecht's theory, that the primitive endoderm can reproduce any cells of the gastrointestinal tract; b) Schaetz's theory, which explains the ectopic cells by implantation during rotation of the gut; c) the dysembryoma theory of Pierre Masson, which considers the diverticulum as a primitive digestive tract and accounts for the heterotopic cells by their failure to undergo involution; and d) Farr and Penke's theory, that the cells represent vestiges of a primitive digestive system which during the first few weeks of fetal life secrete digestive juices for the utilization of the contents of the yolk sac.

Meckel's diverticulum has been found in inguinal, umbilical and femoral hernias.[17] Schwei and Jackson[18] have stated that probably 50 per cent or less of these Meckel's diverticula are incarcerated.

Various types of benign and malignant tumors have been reported to originate in Meckel's diverticula. Polyps, leiomyomas, sarcomas, carcinomas, and carcinoid tumors all have been reported.[19-22]

Clinical Features

Hemorrhage is a common symptom and is due to the presence of heterotopic gastric mucosa with subsequent peptic ulceration. Hemorrhage from the bowel is the most frequent complication encountered in infants and children with Meckel's diverticulum.[7, 23] In Moses' composite review of 1,605 cases,[27] hemorrhage occurred in 30.9 per cent of cases. Hemorrhage usually occurs in children between the ages of 1 and 6 years and rarely is seen in patients over the age of 12 years.[28] In the series reported by Gross,[6] 80 per cent of the patients with hemorrhage were less than 2 years of age. Hemorrhage is from two to five times more common in males than in females.[7, 9, 27]

Clinically, the hemorrhage is usually painless, varying in amount and color from the passage of large quantities of bright red blood to the passage of tarry or chocolate-colored stools. Death due to hemorrhage from ulceration of a Meckel's diverticulum is extremely rare.[8] Gastrointestinal bleeding due to the presence of a Meckel's diverticulum may occur in circumstances other than peptic ulceration. It may accompany intussusception of the diverticulum and inflammation or volvulus of the diverticulum.

Bleeding may be associated with a mild constant or colicky pain which is usually localized about the umbilicus or on the right side of the abdomen. Diarrhea or constipation may be associated. Physical examination rarely is significant except for occasional tenderness to abdominal palpation.

There is a group of patients in whom the Meckel's diverticulum contains

heterotopic gastric mucosa which when examined histologically shows no evidence of inflammation or other disease. The abdominal pain is produced presumably as a result of secretion of hydrochloric acid and pepsin by the heterotopic gastric mucosa which in turn causes irritation in the ileum and in the diverticulum resulting in spasm. This syndrome has been called "dyspepsia Meckeli" by Sibley,[29] who believes that it represents a pre-ulcerative condition in the diverticulum or the marginal portion of the ileum.

Inflammation of Meckel's diverticulum is very similar in its clinical course to acute appendicitis, and it is frequently impossible to differentiate between the two entities. Almost all patients with Meckel's diverticulitis are operated on with the preoperative diagnosis of acute appendicitis. Therefore, when the appendix appears to be normal at operation, Meckel's diverticulum should be sought for.

Brookes[9] has stated that acute Meckel's diverticulitis is rare because the diverticulum is usually relatively short, the opening of the diverticulum in the ileum is large, and the contents are fluid, thus making it less liable to inflammatory change. Crandall and Hirst[7] have stated that Meckel's diverticulitis tends to occur earlier in life than acute appendicitis. In Moses' composite review of 1,605 cases[27], diverticulitis occurred in 10.3 per cent.

Perforation is the third most frequent complication mentioned in the literature and may result from either perforation of a peptic ulcer or advanced diverticulitis. In Moses' review, perforation occurred in 13.8 per cent of the cases. Perforation is said to be due more often to peptic ulceration than to inflammation.[23]

Foreign bodies in a Meckel's diverticulum may cause diverticulitis and perforation. Webb[30] has described 6 cases of perforation of a Meckel's diverticulum due to fish bones, while Persson[31] has reported 10 such cases.

Peritonitis following perforation of a Meckel's diverticulum is usually more severe than that following a perforated appendix. Penberthy and Benson[32] feel that this results from the diverticulum lying farther away from the lateral abdominal wall, so that the process of walling off is not so easily accomplished.

Meckel's diverticulum may cause intestinal obstruction in a number of ways. Moses[27] found that intestinal obstruction occurred in 23.8 per cent of cases. Some authors have stated that the most common pathological change resulting from Meckel's diverticulum is due to obstruction;[5, 9] others have found intestinal obstruction to be the second most frequent complication.[23]

Meckel's diverticulum may act as the leading point of an intussusception; clinical symptoms, signs and course are identical with those seen in intussusception due to other causes. Harkins[33] states that of all Meckel's diverticula showing pathological change, 17 per cent do so by producing an intussusception; Moses[27] puts the figure at 10.9 per cent.

Meckel's diverticulum may act as an axis about which loops of bowel may rotate to form a volvulus; this rarely occurs in most reported series. The incidence varies from 1 per cent of Moses' series[27] to 13.5 per cent in Brookes' series.[9] Clinically there is usually marked abdominal pain, fever and leukocytosis.

A long Meckel's diverticulum or a fibrous cord hanging free from the end of a diverticulum may tie itself in a knot around a loop of small intestine and cause obstruction.

The blood supply of the diverticulum is from a separate branch of the superior mesenteric artery, which occasionally lies in a mesodiverticulum separate from the mesentery of the small intestine. A potential hiatus is formed by the mesodiverticulum, the mesentery of the small intestine and the Meckel's diverticulum, through which internal herniation may occur.

Intestinal obstruction may occur secondary to acute Meckel's diverticulitis.

The presence of a strangulated Meckel's diverticulum in umbilical, inguinal and femoral hernias as a cause of intestinal obstruction has been mentioned previously.

Brookes[9] noted a 7 per cent incidence of persistence of the omphalomesenteric duct associated with abnormalities of the umbilicus; Moses[27] found only a 2.2 per cent incidence.

Mucosal Histology

Berman et al.[28] have stated that when bleeding occurs, nearly 100 per cent of Meckel's diverticula will show gastric mucosa when a careful search is made. It has been shown that the areas of gastric mucosa may be small and scattered.[9] Therefore, unless serial sections of the entire diverticulum are examined, small areas of heterotopic gastric mucosa may be missed. Cobb[34] collected 100 cases of peptic ulceration occurring in Meckel's diverticulum and found positive histological evidence of gastric mucosa in only sixty.

Diagnosis

Preoperative diagnosis of a complication arising from the presence of a Meckel's diverticulum usually is presumptive, since most of the pathologic states are indistinguishable from similar complications arising in other abdominal organs. Hemorrhage from the diverticulum must be diagnosed by excluding the possibility of bleeding from other sources. Occasionally a Meckel's diverticulum can be demonstrated by roentgenographic examination with barium.

Differential diagnosis is concerned mainly with other acute abdominal conditions. Acute appendicitis, perforated ulcer, and intussusception should always be considered; when bleeding occurs, hemorrhagic diseases, hemangiomas, peptic ulcer, small bowel tumors and polyps must be ruled out.

Treatment

Most patients are operated upon because of some complication of the Meckel's diverticulum such as hemorrhage, obstruction or perforation. If hemorrhage has been severe, preoperative correction is of extreme importance. The complication of the Meckel's diverticulum must be relieved and the diverticulum excised.

The opinion has been repeatedly expressed that a Meckel's diverticulum should be removed whenever it is encountered at laparotomy, provided no contraindications exist to additional surgery. Justification for removal is the possible serious consequence of the complications to which patients with Meckel's diverticulum are subjected. At the time of surgery it is impossible to rule out the presence of heterotopic gastric mucosa by inspection or palpation.

The mortality arising from the various complications of Meckel's di-

TABLE 1

Meckel's Diverticulum Encountered Incidentally at Surgery

Age	Sex	Symptoms	Operation	Primary pathology	Mucosal lining of diverticulum
5 weeks	male	right scrotal mass	right inguinal herniorraphy	right inguinal hernia	ileal
10 years	male	intermittent nausea, vomiting and abd. pain one week	appendectomy and diverticulectomy	acute appendicitis	ileal
10 years	female	progressive periumbilical pain and vomiting	appendectomy and diverticulectomy	acute appendicitis	ileal

TABLE 2

Age and Sex Incidence

Age in years	Male	Female	Total
0–1	1	1	2
1–2	0	1	1
2–3	0	1	1
3–4	2	0	2
4–5	1	1	2
5–8	5	0	5
8–10	1	2	3
10–12	3	3	6
	13	9	22

verticulum varies from 7 to 58 per cent, depending on the severity of the condition and the time of surgery.

ANALYSIS OF CASE MATERIAL

This report is based on 22 cases in which the presence of a Meckel's diverticulum was established at the time of surgery and substantiated by histopathological examination. These were observed at Children's Hospital during a period of 7½ years from January 1952 to June 1959 inclusive. In 3 patients the diverticulum was an incidental finding at the time of surgery for other conditions (table 1), leaving 19 cases in which the symptoms were attributable to the presence of the diverticulum.

Table 2 constitutes a summary of the age and sex incidence in this series. Meckel's diverticulum most commonly produces symptoms in patients under one year of age;[22] this, however, was not true in the present series. There were no Negro patients encountered, although approximately 50 per cent of all patients admitted to this institution are Negro. An apparent lower incidence of Meckel's diverticulum in the Negro race has also been noted by Michel et al.[24] from the Charity Hospital in New Orleans and by Moore[25] at the Indiana University Medical Center. The reason for the low incidence in the Negro race is not apparent. Meckel's diverticulum causes complications more frequently in male than in female patients varying from a ratio of 2:1 to 4:1 in different series.[5, 8, 9, 11, 18, 26] Thirteen of the 22 patients in this series were male.

TABLE 3

Meckel's Diverticulum Associated with Melena

Age	Sex	Symptoms	Hemoglobin, Gm./100 cc. blood	Operation	Mucosal lining of diverticiculum	Length of time of symptoms prior to surgery
16 m.	F	melena diarrhea	10.6	diverticulectomy and appendectomy	gastric	1 day
9 y.	F	melena abd. pain	10.8	resection ileum and appendectomy	gastric	3 months
4 y.	F	melena (intermittent)	12.1	diverticulectomy and appendectomy	ileal	2 years
7 y.	M	melena abd. pain	9.0	resection ileum and appendectomy	ileal	8 months
8 y.	M	melena	7.9	diverticulectomy and appendectomy	gastric	3 days
12 y.	M	melena	9.4	diverticulectomy and appendectomy	gastric	11 days
7 y.	M	melena	9.4	diverticulectomy and appendectomy	gastric and ileal	2 days

TABLE 4

Meckel's Diverticulum Associated with Abdominal Pain

Age	Sex	Operation	Mucosal lining of diverticulum	Length of time of symptoms prior to surgery	White blood cell count (thousands per cu. mm.)
7 y.	F	diverticulectomy and appendectomy	ileal	12 hours	24.5
5 y.	M	diverticulectomy and appendectomy	ileal*	1 week	10.2
10 y.	M	resection ileum and appendectomy	ileal	30 hours	11.5
3 y.	M	diverticulectomy and appendectomy	ileal	12 hours	13.8
10 y.	F	diverticulectomy and appendectomy	ileal	24 hours	13.1
11 y.	M	diverticulectomy and appendectomy	ileal and pancreatic†	2 days	32.6
8 y.	F	diverticulectomy and appendectomy	ileal	3 days	14.2
2 y.	F	diverticulectomy and appendectomy	ileal†	8 days	14.1
11 y.	F	diverticulectomy	ileal and gastric	10 days	6.5

* Perforated by fish bone.
† Perforated.

In 7 patients the chief symptom was evidence of bleeding into the gastrointestinal tract (table 3). No patient was less than 1 year of age. Four of the seven were male. The blood in the stools was described variously as bright red, reddish-brown, or tarry in appearance, and the quantity ranged from streaks of blood to 500 ml. The bleeding was "silent" in 5 patients, while in 2 patients there was mild intermittent abdominal pain. The hemoglobin content ranged from 7.9 Gm. to 12.1 Gm. per 100 ml. of blood. The white blood cell count ranged from 7,900 to 12,100 per cu. mm. The correct diagnosis was suspected preoperatively in all patients.

In 9 patients in this series pain was the chief complaint (table 4). Pain was most frequently acute and severe and occurred most often in the periumbilical area or the right lower quadrant of the abdomen. Four of the patients were male. The youngest patient was 2 years of age and the oldest 11 years of age. The preoperative diagnosis in all cases was acute appendicitis. Leukocytosis was present in 8 of 9 patients and ranged from 10,200 to 32,000 leukocytes per cu. mm. The white blood cell count in the remaining patient was 6,500 per cu. mm.

Perforation of Meckel's diverticulum occurred in 3 patients in this series;

TABLE 5

Meckel's Diverticulum Associated with Intestinal Obstruction

Age	Sex	Symptom	Operation	Mucosal lining of diverticulum	Remarks
4 y.	M	progressive abdominal pain and vomiting 1 day	reduction of volvulus, diverticulectomy and appendectomy	gastric	
3 m.	F	projectile vomiting progressive abdominal distention 1 day	resection of terminal 6″ of ileum and diverticulectomy	ileal	diverticulum contained inflammatory exudate within the lumen; ileum infarcted
3 y.	F	vomiting 1 day	diverticulectomy and appendectomy	gastric	tip of diverticulum adherent to mesentery of ileum forming a loop through which some small bowel herniated. Diverticulum was markedly inflamed.

one case of diverticulitis and perforation occurred as a result of a foreign body lodging in the diverticulum.

There were 3 cases of Meckel's diverticulum associated with intestinal obstruction (table 5). There was one case of volvulus. There were no abnormalities of the umbilicus associated with persistence of the omphalomesenteric duct in this series.

Histopathological examination was performed on the 22 Meckel's diverticula removed surgically. Eight of the diverticula contained gastric mucosa, one of which also contained pancreatic tissue. In thirteen of the diverticula, normal small intestinal mucosa was present.

Diverticulectomy was performed in 17 cases and intestinal resection in 5 cases. There were no deaths in this series nor have there been any admissions for recurrent symptoms.

Appendectomy was performed in 6 of the 7 cases in which melena was the presenting symptom and in all ten of the cases in which pain was the chief presenting symptom. Histopathological examination revealed a normal appendix in all cases.

SUMMARY

Twenty-two cases of Meckel's diverticulum in children have been presented; nineteen were removed because of complications. The complications

which occur in a Meckel's diverticulum include infection, peptic ulceration, hemorrhage, perforation, intestinal obstruction, volvulus, intussusception and neoplasm. On histopathological examination of the 22 Meckel's diverticula in the present series eight contained heterotopic gastric mucosa.

Meckel's diverticulum should be sought if, at the time of surgery, no other pathologic condition is found to explain the clinical findings which led to surgery. In children, Meckel's diverticulum should be removed when found if no contraindications to additional surgery exist. The removal of an uncomplicated Meckel's diverticulum is a simple and safe procedure, while its presence in the abdomen is a potential source of danger.

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Traumatic Myositis Ossificans (Circumscripta)

TIMOTHY H. DALEY, M.D.*

The formation of a true bony tumor involving or adjacent to muscle tissue may present a difficult diagnostic problem. When there is an accompanying history of local muscle injury, a diagnosis of traumatic myositis ossificans should be strongly considered.

For various reasons the term myositis ossificans has been considered by some to be inappropriate and misleading. Other names which have been ascribed to this benign condition include: heterotopic bone formation,[1, 2] ectopic ossification,[3] atypical myositis ossificans,[4] myositis ossificans post-traumatica,[1, 5] metaplastic ossification,[1, 3] extra-osseous localized non-neoplastic bone and cartilage formation,[6] and circumscribed myositis ossificans.[7]

Although the name myositis connotes inflammation of muscle tissue, an older lesion may not contain inflammatory cells. Further, muscle tissue may not be directly involved in the final pathological picture. In some cases the calcification is far removed from skeletal bone;[1, 4-6, 8] osteoid tissue or cartilagenous matrix alone may comprise the early lesion.[7] Simple descriptive titles have therefore been suggested. Nevertheless, in the majority of cases cited in the literature there is a history of muscle injury or stress and resultant local alteration of muscle prior to ossification; thus the name traumatic myositis ossificans probably best applies. There is a need for a strong index of suspicion of this entity in evaluating calcific tumors incident to trauma. Final diagnosis and, more importantly, early differentiation from the often conflicting impression of neoplasm depend primarily on confirmatory histologic examination.

Etiology and Pathogenesis

In some cases of traumatic myositis ossificans the precipitating factors may not be clearly evident. However, a careful history will usually uncover some previously undetected or ignored local trauma. A simple blow from a striking object or from a fall, recurrent minor athletic injuries, gunshot wounds, fractures, sprains, dislocations, joint damage, and severe muscle strain (e.g., difficult labor)[8] have all been cited as obvious causes. In patients with paralytic poliomyelitis[9] and hemiplegia or paraplegia, chronic unrecognized trauma to muscle may result during the course of passive exercising, massage, skin grafting, dressing changes and routine nursing care. Johnson[4] has reported three such cases where extra-articular ossification, ankylosis,

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and associated soft tissue contractures occurred during long hospitalization for burns. Postoperative scar tissue may also afford a nidus for ossification. Bony tumors have been observed to develop in scars following suprapubic prostactectomy, cholecystectomy, and gastrectomy.[1, 2, 5]

A possible clue to the pathogenesis of osseous tissue formation seen within surgical scars of the abdomen has been suggested by McGinnis and Leavitt.[1] Both the linea alba and linea transversa (which are divided by midline abdominal incisions) may contain osteogenic rests of rudimentary sternum and rib. McGinnis and Leavitt postulated that either these rest cells or normal fibroblasts can be stimulated by muscle injury to ossification. Mosiman's experimental studies on guinea pigs[10] support his belief that heterotopic bone growth depends on the presence of osteoblasts from pieces of living bone and periosteum. This view is strengthened by the evidence (cited by Sanders) that the strain of muscle fibers at the point of insertion on bone may dislodge periosteal or osseous fragments which then act as foci for extra-osseous bone growth.[4, 5] Sanders goes further, however, to point out that muscle, tendon and connective tissue, because of their mesenchymal origin, contain bone-forming elements which may be triggered by any agent or injury sufficient to cause proliferative repair. Heinen and associates,[3] on the other hand, have offered evidence in rabbits which suggests that calcification can occur in the absence of any osteogenic substance.

It is probably direct periosteal trauma occurring through muscle tissue which most commonly precipitates osseous tumor growth within tissue contiguous to a bony surface. Periosteal proliferation alone can account for the ossification in such cases.[7]

Additional theories have indicated that the increased calcium concentration within hemorrhagic effusions into traumatized and congested muscle may serve to augment calcium deposition. Altered protein coagulability secondary to local or systemic disease, systemic toxins, and individual predisposition have also been included among the possible etiological factors.[8] Periosteal thickening and new bone formation have been known to accompany circulatory insufficiency, venous stasis, or edema from various causes.[4] Metabolic, endocrine, and electrolyte disturbances have been generally mentioned in the literature in relation to extraskeletal ossification.[4, 8] "Congenital alteration of mesenchyme" has been considered by Burdach[11] as a possible etiology of metaplastic ossification.

Incidence

Traumatic myositis ossificans is a rare condition. It can occur at any age but is more common in adolescence and early adulthood. The male, and especially the athlete, is predominantly affected. Twenty-one of twenty-five cases reported by Geschickter and Maseritz[7] involved males. Racial inci-

dence is not significant. The usual anatomic location of the lesion is either the arm or leg. In one series reported by Ackerman,[6] 50 per cent of the tumors were seen in the flexor muscles of the upper arm, particularly the brachialis anticus, and 44 per cent in the leg, most commonly involving the quadriceps femoris and the adductors of the thigh. The gluteal muscles, neck and facial muscles (e.g., masseters), abdominal and lumbar muscles, and muscles of the hand and foot are all rare sites of osseous growth.[8]

Pathology

The pathology of traumatic myositis ossificans varies with the stage of maturation of the lesion. Calcification, although usually not occurring before four to eight weeks, has been reported as early as 19 days following muscle trauma.[7] Nonspecific changes secondary to injury, e.g., hematoma formation, inflammation, muscle degeneration, bands of tissue proliferation, and fibroblastic activity, occur first; osteoid tissue forms later.[6, 7] In this early stage there is little if any organization. Many atypical cells and even mitotic figures, which may simulate malignant proliferation, form the central core of the lesion. In time, osteoid tissue surrounds this cellular area, and, in turn, calcification is laid down peripherally as osteoid becomes true bone. Three separate zones are thus formed, i.e., inner cellular, middle osteoid, and outer bony. This "zone phenomena" (Ackerman)[6] remains to some degree until bone formation has progressed sufficiently to include the entire lesion. A cartilaginous cap may form later, according to Ackerman, as the bone further differentiates. The so-called post-traumatic osteochondroma, a benign tumor, is probably a variant of traumatic myositis ossificans formed in this way.

Histologic diagnosis, which is especially valuable in the absence of a classical clinical history and in identifying atypical tumors which must be differentiated from neoplasm, is based, then, on varying and progressive features: 1) early "zone phenomena" with differentiated osteoid tissue, 2) oriented osteoid and peripheral true bone in older lesions, or 3) true bone alone with normal stroma and fibrous encapsulation in completely calcified lesions.

Clinical Findings

Local swelling is commonly the first objective finding. This may appear immediately following trauma as a nonspecific response to tissue injury or may manifest itself weeks or months later as the initial sign of tumor formation. Induration is first palpable in the peripheral portions of the soft tissue mass. It either usually coincides with, or is evident after, roentgenographic appearance of calcification.

The true bony mass, once demarcated, may be smooth or irregular, round

or elongated, solitary or multiple, and is usually immobile. Overlying cutaneous tissue may be secondarily involved, either by calcium deposition or ischemic changes due to pressure of the mass. Occasionally, calcium spicules penetrate through the skin.

Pain, a variable symptom, is usually experienced locally during the initial period of inflammatory swelling, but is frequently absent after calcification has occurred, unless pressure effects on nerve, bone, or muscle tissue are significant. Deep palpation of a tumor will often elicit some degree of pain.

In addition, nonspecific findings such as muscle spasm and contracture, ankylosis, nerve palsy and paresthesia, low back pain, wry neck, limp, and abdominal ventral hernia have been reported in association with traumatic myositis ossificans.[1, 4, 6, 8, 9] Regression with complete disappearance of small tumors has been reported; this has been attributed to osteoclastic absorption of bone by surrounding muscle tissue.[6]

Laboratory Findings

Serum calcium, phosphorus, and alkaline phosphatase determinations are consistently within normal range, although during the stage of calcification alkaline phosphatase may be produced in greater than normal amounts in the tissues resulting in a transitory rise in the serum levels.[11] Hematological and urine examinations are normal in this condition. Alterations in other blood chemistry determinations have not been reported.

Roentgenographic examination is invaluable but must be interpreted in conjunction with histologic and pathologic findings. The stage and degree of soft tissue calcification, the presence of periosteal bone proliferation, the amount of tumor delineation and osseous lamination, and the proximity to or attachment to skeletal bone are some of the typical but nonspecific x-ray features. Densities due to bony calcification do not appear before three to four weeks after injury, and as a rule are not seen until much later, usually after clinical observation of a swelling or definitive mass. Because of the radiological similarities between neoplastic and non-neoplastic bony tumors, it is frequently difficult and unwise to exclude malignancy on the basis of x-ray appearance alone. This is especially true when dealing with an early lesion, when the history is obscure and the period for clinical appraisal has been too short. Biopsy is imperative at this time.

Diagnosis

If biopsy is postponed and the final diagnosis of an atypical tumor must await histologic confirmation, the clinician is faced with a number of possible diagnoses to be excluded. Foremost are neoplasms since prognosis depends on early recognition and excision. Included in this group are all malignancies which can cause primary or metastatic periosteal bone prolifer-

ation, such as osteosarcoma, Ewing's sarcoma, extraosseous sarcoma, neuroblastoma, Wilms's embryoma, leukemia, and invasive lymphoma. Ackerman[6] has reported 21 cases of traumatic myositis ossificans in which a diagnosis of neoplasm was initially considered.

Conditions which may stimulate nonmalignant local periosteal and osseous proliferation must also be differentiated. Osteomyelitis, periosteal abscess, systemic infection, subperiosteal hemorrhage (of variable etiology), syphilis and tuberculosis fall into this category. Osteitis and periostitis may be the result also of generalized disease such as one of the collagen disorders, multiple myeloma, parathyroid dysfunction, Paget's disease, fibrous dysplasia, renal osteodystrophy, and some vitamin deficiency states.

Muscle and connective tissue pathology of many kinds may resemble clinically traumatic myositis ossificans. Fibrous myositis, acute purulent and hemorrhagic myositis, early progressive myositis ossificans, calcified fibromyxoma, universal calcinosis (early), trichinosis, dermatomyositis, myogelosis, keloid formation, sarcomatosis, tuberculous spondylitis, cephalohematoma, and exostosis may all precipitate similar localized tumors within or connected to muscle or connective tissue.

Bone and joint deformities secondary to rheumatoid disease may conceivably mimic this condition, but this has not yet been reported.

Treatment

Effective treatment of traumatic myositis ossificans consists of total surgical excision. Resorption of ossified tumors has been described but only as a rare occurrence, and is probably due to prolonged muscle action against the lesion (e.g., near the knee).[6] Calcification has been reported to recur occasionally within surgical scar tissue following the excision of a bony tumor.[5] This reossification has been attributed to premature excision of a lesion before complete demarcation of the bone has taken place.[8]

Application of local therapy (e.g., heat packs, infrared radiation, liniments) during the earliest stages of swelling is directed at the alleviation of inflammation and hematoma formation.

Steroids have been credited with causing temporary regression of some of the lesions of early progressive myositis ossificans; the ossified portions of well defined tumors, however, were not affected.[11, 12] The value of these agents in traumatic myositis ossificans has not been investigated.

Radiation, injection of lytic enzymes, and massage are mentioned by Sanders[5] only to be condemned as valueless and dangerous. The proper handling of the immobilized patient may prevent those atypical ossifications related to paralysis and burns.

Prophylaxis against ordinary trauma is, of course, most important when a predisposition toward traumatic myositis ossificans exists. In addition,

therapeutic procedures such as intramuscular and intravenous injections, skin tests and immunizations, manipulations for fracture or dislocation, and surgical incisions should be recognized as potential stimuli for tumor formation.

SUMMARY

Certain aspects of etiology and pathogenesis of traumatic myositis ossificans are described. Particular stress is laid on the role of surgical biopsy in confirming the diagnosis. Consideration is given to the value of a complete history, careful clinical observation, and x-ray evaluation in diagnosing the tumor. A differential diagnosis is briefly outlined, and the need for early exclusion of neoplasm is emphasized. Recommended treatment is directed toward effective removal, prophylaxis against recurrence or formation of new lesions, and the prevention of pain, deformity, and disability.

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Clinical Pathological Conference

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PRESENTATION OF CASE

This 3 year old white girl was admitted to Children's Hospital for the first time because of crampy abdominal pains, progressively enlarging abdomen, vomiting, and diarrhea. Her health had been good until two months prior to admission, when she first began to have crampy abdominal pains accompanied by diarrhea a few days later. She also had a fever and ultimately was seen by a physician who examined her by fluoroscopy and prescribed a "sulfa" suppository. Then, except for the history of a progressively enlarging abdomen, she did well until 10 days prior to admission when abdominal distention became more marked and she began to vomit.

During the time the admission physical examination was conducted, she vomited green-stained fluid and passed a liquid yellow-brown-greenish stool. Her temperature was 100°F., pulse rate 130 to 140 per minute, respirations 30 to 40 per minute, and blood pressure 110–120/60–70 mm. Hg. Significant physical findings were confined to the abdomen which was distended by a hard, irregular, slightly tender mass in the left lower quadrant; there was a similar but smaller mass in the right lower quadrant; a less distinct mass also was felt in the right upper quadrant, and a large, smoothly outlined mass filling the pelvis was felt on rectal examination. The liver was not felt. The skin had fair turgor but was pale.

Admission laboratory determinations included a blood urea nitrogen of 18 mg. per 100 ml., a carbon dioxide combining power of 12 mEq./L. (28 volumes per cent), a serum sodium of 145 mEq./L., and a serum potassium of 4.4 mEq./L. The hemoglobin was 10.7 Gm. per 100 ml. The white cell and differential counts were normal.

Immediately after admission the child received electrolyte-containing solutions intravenously and shortly thereafter received a transfusion of packed erythrocytes.

A roentgenogram of the chest taken on the day following admission was

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FIG. 1. Urogram showing evidence of dilatation of the calyces and the pelvis, and some kinking of the right ureter at the ureteropelvic junction with dilatation of the right ureter; supernumerary kidney and ureter on the left side.

normal; views of the abdomen in the prone and upright position revealed no definite evidence of pathology. The bladder was noted to be distended with urine. Urographic examination (fig. 1) by the intramuscular route showed that both kidneys functioned well. On the right, there was evidence of dilatation of the calyces and the pelvis and some kinking of the ureter in the region of the ureteropelvic junction. The calyces were well cupped. The ureter was somewhat dilated throughout its course. At the end of 48 minutes there was a significant amount of dye in the bladder. There was a shadow extending from the lateral aspect on the right side which seemed to be a portion of the bladder and was thought to be of no pathological significance although a ureterocele low in the right ureter was considered. On the left, there was a supernumerary kidney. Both kidneys on the left side and their pelves as well as the upper three fourths of their respective ureters were visualized. It was not possible to state whether the ureters extended into the bladder independently or fused distally.

Two days after admission, serum electrolyte determinations, including sodium, potassium and chloride, were within normal limits; carbon dioxide combining power was 20.3 mEq./L. The peripheral blood count was still

normal. A urinalysis was also normal except for the presence of one plus acetone; the specific gravity was 1.018.

That same day she became somewhat lethargic and irritable, and complained of pain in the abdomen. The abdomen was still distended. She vomited a moderate amount of yellowish fluid.

Three days after admission a laparotomy was performed. During the closure of the abdominal wall cardiac arrest occurred. Transthoracic cardiac massage was done for 19 minutes with no sustaining effect. She was then pronounced dead.

DISCUSSION

Dr. Philbin:

This is a 3 year old girl whose illness began two months prior to admission to the hospital. Interestingly enough, the illness commenced with diarrhea and crampy abdominal pain. One is not told where the pain was localized so one must assume that it was diffuse. One is not told whether this pain was acute, severe and continuous, or whether it consisted of mild intermittent cramps. Diarrhea ensued shortly thereafter. Apparently the physician who examined her was not impressed with anything in the abdomen. She then did fairly well except for progressive enlargement of the abdomen until 10 days prior to her admission at which time she began to vomit. This is all the history that is given. One must assume that after the physician's visit the child was eating, not vomiting, and that her bowel movements became normal.

This process appears to have been chronic rather than acute, and it was not interfering with the economy of the child to any great extent. One would like to know if she had lost any weight prior to this initial episode. Did she look pale? Had she been listless or lethargic? One would also like to know if the physician gave her any more medication: did she have appendicitis suppressed by antibiotics which went on then to abscess formation? Was there any blood in her stool? This is important if one were to consider intussusception or even a neoplasm of the bowel. It would, therefore, be important to know the character of the stools.

On admission to the hospital, the child was febrile, had tachycardia, was pale, but was apparently adequately hydrated. The turgor of the skin was fair. The important findings on examination were distention of the abdomen, a mass in the left lower quadrant (which was the probable cause of this distention), and the passage of a green stool. At first one could think that she had intestinal obstruction and that enlarged bowel was causing the distention; however, the examiner noted that the distention was due to a firm, nodular, tender tumor arising in the left lower quadrant. He described a similar but smaller mass in the right lower quadrant. He then described an ill defined mass in the right upper quadrant.

The chest and the heart were normal. On rectal examination, a smooth mass was felt filling the pelvis. Was this mass anterior or posterior? Was it present after catheterization? An important finding was that this mass was not particularly tender. This is unusual for an abscess, an inflammatory process, or for a mass of inflamed bowel.

The mass in the right lower quadrant was probably part of the mass in the left lower quadrant. From the x-ray films, it appears that the right kidney was dilated. The mass in the right upper quadrant could be an enlarged kidney, or it could be liver. The important finding in this examination is the character of these masses: they are firm and multiple. This is certainly indicative of a tumor.

I think that the pathology here is neoplastic. However, one must mention appendicitis and abscess formation. The reasons for such a consideration are the rapidity of onset, the absence of significant findings on the initial examination, and ignorance of the therapy instituted by her first examiner. It is difficult to imagine a mass of the size described on her admission to this hospital as having been undetectable by even the most careless examiner just 60 days earlier, unless the mass was of inflammatory origin. The therapy proffered is most important, for antibiotics have produced cases of bizarre appendiceal disease. I have seen very large, relatively cold abscesses as a result of such practices. I prefer to believe, however, that one has the correct information regarding treatment and that the mass could have been undetected by the original physician.

Examination of the x-rays at this time reveals findings not adequately described in the protocol. In reviewing the intravenous urogram, there appears to be a definite deformity of the bladder. The shadow seen on the left side of the bladder was thought by the radiologist to be a ureterocele; this was difficult for me to understand via the protocol, because a ureterocele does not proceed from the lateral wall of the bladder: it is usually noted to bulge into the bladder lumen. I do not think that this is a ureterocele, but, instead, a deformity of the left dome of the bladder produced by pressure from an extrinsic mass. In addition, there is dilatation of the right ureter and right kidney as well as some distention of the colon, the former suggesting lower ureteral obstruction.

Given a child with a history of diarrhea and vomiting, abdominal distention, and a palpable mass in the abdomen, what would the next step be? One would like to have a chest film (which was negative) and a skeletal survey. If ascites were present, one would also like an abdominal paracentesis for knowledge of the nature of the sediment cells would be helpful. X-rays visualizing the integrity of the sacrum would have been useful, thinking in terms of a chordoma or of a sacrococcygeal teratoma. Ultimately, one must depend on a laparotomy for the diagnosis.

What are the tumors which can affect a 3 year old child? The first one I

would think of is a Wilms's tumor. Against this diagnosis are the facts that this is a bilateral pelvic tumor and that the urogram shows nothing more than dilatation of the ureter and pelvis. Renal deformity is not essential, but to make a diagnosis of a Wilms's tumor in its absence would be precarious.

Teratomas are interesting tumors and would be more possible in this case. They are usually benign. The mortality associated with them is quite high, between 70 and 80 per cent, not because of their malignancy in most cases, but because of the difficulty in removing them, their recurrence, local extension and involvement of vital structures. Most teratomas appear within the abdomen. They may appear as sacrococcygeal teratomas, arising anteriorly or posteriorly. Those arising anteriorly may grow to large size before being detected. There may be some destruction of the bony structures in the vicinity. Most of these tumors produce some displacement of the kidney, usually superiorly, occasionally inferiorly. The teratoma is a lobulated tumor. It is soft. It is usually unilateral but may extend across the midline. It usually occurs during the first year, about 30 per cent being seen during this period. It may show evidence of calcification. (This finding is not specific and may also be seen in Wilms's tumor and neuroblastoma.) In the teratoma we may be able to demonstrate definite organic formation, such as teeth or bones; this is very helpful when it occurs. The tumor, when it is malignant, is very fast growing and almost 100 per cent fatal. There is usually one cell type which is predominant and this is very anaplastic.

The soft tissue sarcomas are not uncommon in children. Fifteen per cent of retroperitoneal sarcomas occur in children. They are very difficult to remove and often result in a crippled child. These soft tissue sarcomas range from the embryonal rhabdomyosarcoma, which is a very rapidly growing tumor of childhood and is rarely amenable to treatment by radical surgery, to the liposarcoma which is less dense than the tissue about it, is seen as a translucent tumor on x-rays and is somewhat susceptible to x-ray therapy. These tumors are indistinguishable from one another. It is impossible by abdominal palpation alone to say whether the tumor is a lipoma, fibroma, sarcoma, or an embryonal rhabdomyosarcoma.

The chordoma is an interesting tumor. Chordomas arise from notochordal remnants and may present ventrally or dorsally in the sacral region, very occasionally in the cervical area. It is a serious tumor, usually fatal through local destruction of vital structures, although it has been known to metastasize. Adequate removal usually results in absolute lack of control of the bladder and rectum, and, not infrequently, useless lower extremities. It is midline in location and a tumor of the size of that under discussion would be expected to have destroyed bone.

The other tumors I wish to discuss are the neuroblastomas and the lymphomas. In children with lymphomas, initial abdominal symptoms are twice as frequent as in adults, and tumors localized in the abdomen may manifest themselves in many ways, particularly those involving the gastrointestinal tract. Rosenberg,[1] in a recent review of the lymphomas of childhood at Memorial Hospital, found 23 per cent of these tumors to arise intra-abdominally, as opposed to 10 per cent in adults. Lymphomas can arise without associated peripheral lymphadenopathy and can grow to large proportions with no symptoms other than those of the locale of origin. With involvement of the intestinal tract, the patient may have severe diarrhea, nausea, vomiting and all of the symptoms which this child portrayed. The lymphomas are relatively uncommon in children and, when apparent, are more often found at an age greater than 5 years. It would be most unusual to have an abdominal tumor of this size without hilar adenopathy. I would reject this diagnosis in favor of the following.

I feel that this child had a neuroblastoma, one of the most common abdominal tumors of this age group, although, of course, more common during the first year of life. It is uncommon in the pelvis, but Bodian,[2] of Great Ormond Street Hospital, reported about 8 per cent of his neuroblastomas to have arisen therein. About 70 per cent of his cases originated in the vicinity of the adrenal glands, two thirds from the gland itself, one third from the nonadrenal sympathetic ganglia in the vicinity. Those arising in the pelvis may be notoriously silent until they attain a considerable size, and they may initiate many gastrointestinal disturbances. Metastases may be the first indications of the presence of a neuroblastoma. Bladder obstruction alone may be the first sign. If such a lesion is suspected, a skeletal survey should be swiftly requested and the distinctive findings would be most helpful, if present. Such a survey was not done in the case under discussion. Punctate calcification in the tumor itself is not specific and it is not always present.

How does one prove the diagnosis? One can not, short of obtaining the tissue itself. I would mention here that an aspiration biopsy could have proven most valuable in forewarning the surgeon of the pathology he was to confront.

I believe this to be a tumor, a neuroblastoma, and will be most surprised should an abscess be encountered. I think there is extension of the tumor across the pelvis to the right lower quadrant, obstructing the right ureter and compressing the bladder dome. The tumor palpated in the right upper quadrant could be dilated kidney. It could also be liver or additional tumor.

It might be well at this point to mention an interesting syndrome, recently described and confirmed by different observers, consisting of intractable,

debilitating diarrhea in children relieved by the removal of otherwise asymptomatic neurofibromas, some in distant extra-abdominal locations. I do not feel this to be the case at hand.

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Dr. Guin:

This little girl was found to have lymphosarcoma. The patient was first seen elsewhere, so we do not have a complete history.

Every organ in the abdomen was involved in the neoplastic process and the pancreas was almost entirely destroyed. One cannot say where this lymphosarcoma arose. The entire mesentery was involved, as were the lymphoid tissue in the intestinal tract and the mass of nodes about the porta hepatis. The spleen had been invaded in a small area. The uterus, fallopian tubes and ovaries showed massive, symmetrical involvement. The uterus weighed 150 Gm. as opposed to the normal of 2 Gm. in a child of this age. The ovaries weighed 50 Gm., the normal being 0.5 Gm. The

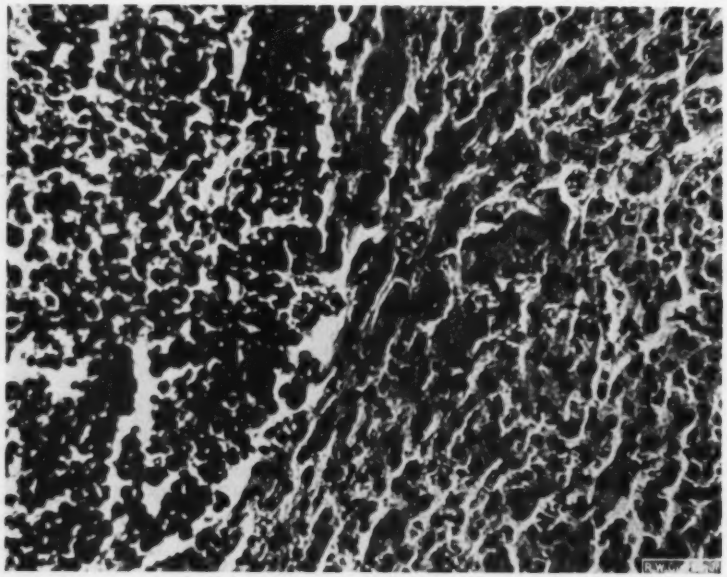

Fig. 2. Area of liver disclosing focus of invading lymphosarcoma which has replaced hepatic cell cords.

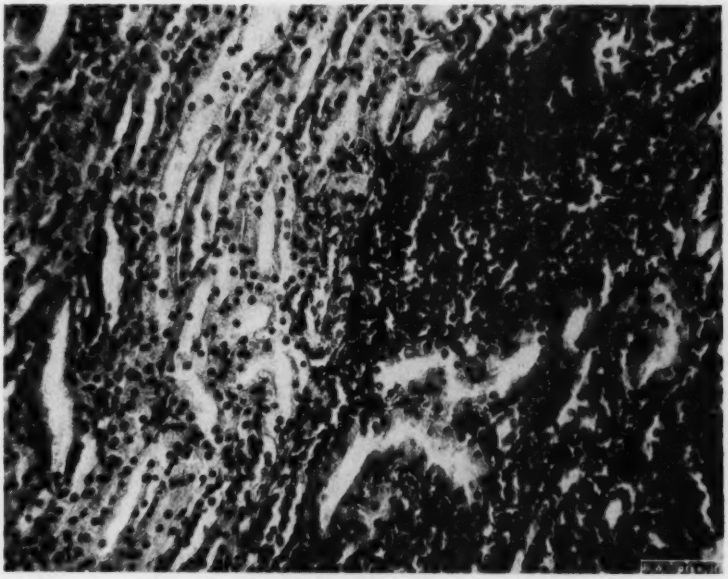

FIG. 3. Lymphosarcoma encroaching upon the kidney

large uterus could have been responsible for the depression noted in the bladder.

The liver and kidneys revealed many areas of metastasis (figs. 2 and 3). The central nervous system and thoracic cavity were free of disease. Other remaining lymph node groups were not involved. Our experience differs from that at Great Ormond Street Hospital. In contrast to their patients with lymphosarcoma, our patients are in a younger age group. The absence of involvement of the peripheral lymph nodes does not rule out lymphosarcoma.

No classification of lymphomas is entirely satisfactory. As a rule, the tumors in this age group which one calls lymphosarcomas are made up of moderately large round cells suggesting immature lymphocytes but with more pleomorphism of the nuclear chromatin.

Results of attempts to differentiate these tumors by various factors appearing in the serum are still questionable. In the rat, serum measurements made in acute and chronic lymphocytic leukemias show no elevation of the lactic dehydrogenase. The findings in animals, however, cannot always be correlated with findings in the human. Fifty per cent of children with lymphosarcoma will have some elevation of the serum lactic dehy-

drogenase as well as of the glutamic oxalacetic transaminase. The reasons for this are not very well delineated.

Dr. Wigger:

During the years from 1951 to 1960 the diagnosis of lymphosarcoma was made 11 times at this hospital. In eight of these patients the age at the onset of the disease ranged from 2 to 6 years. One patient was less than 1 year of age and two were between the ages of 6 and 12 years. The duration of symptoms until the diagnosis was made was less than one month in 8 cases and from one to six months in 3 cases. The survival time of the patients from the time the diagnosis was made was less than six months in 8 cases, and 1 case fell into the range 6 to 12 months. Two patients lived longer than six months but there is no follow-up subsequent to that date.

There was a large variety of presenting clinical features; symptoms of upper respiratory tract infection, vomiting, peritoneal and pleural effusion, and abdominal enlargement being the most frequent; others were cervical adenopathy, fever, and hepatosplenomegaly. One patient had hemiplegia, while another presented with the clinical picture of acute appendicitis.

The primary sites of involvement were the cervical lymph nodes in four instances, the abdominal nodes in three, and the mediastinal nodes in two. The tonsils and the appendix proved to be the primary locations in one case each.

The treatment consisted mainly of combinations of radiation and chemotherapy. Nine patients received roentgen therapy; four, triethylene melamine; three, nitrogen mustard; and two, 6-mercaptopurine, amethopterin, and cyclophosphamide.

Dr. Rice:

Today approximately 10 to 15 per cent of all the children who die at this hospital succumb to the effects of malignant tumors and leukemia. Tumors now occupy a prominent place in the mind of today's pediatrician, whereas such conditions gave him little concern in the past; as a result they are being recognized earlier than they formerly were. The establishment of the Tumor Board at this hospital was very useful in this respect because it brings members of various medical disciplines from the hospital staff together to consider these problems.

It is important for the physician to realize that if the patient with cervical adenopathy is to receive the greatest benefit he must institute treatment promptly. "Diagnostic" doses of x-ray should be avoided in trying to make a diagnosis, and, whenever possible, the tumor should be biopsied.

CLINICAL PROCEEDINGS NOTE

Introducing a New Facility to the Metropolitan Area

On June 19, 1961 the Home for Retarded Children established by the Jewish Foundation for Retarded Children, Inc. was officially opened. This new facility is located at 6200–2nd Street, N. W. The Jewish Foundation, a nonprofit, nonsectarian group, has designed the Home to provide both a day care center for thirty children and, in September 1961, a residential program for approximately thirty-two retardates.

In addition to the day care and residential facilities, the Home will attempt to provide a much needed "way-station" concept, offering temporary placement for children in three special categories:

1. Retarded children needing immediate institutionalization. These could be housed for several months; the social service staff will aid with the permanent placement decisions if desired.
2. Retarded children whose parents are unwilling or unable to recognize the need for institutionalization. It is felt by many authorities that observation of the child in an institutional setting for a short period may be beneficial for the parents' acceptance of the doctor's recommendations.
3. Newborn infants suspected of being retarded. These would be admitted for short term care and diagnostic observation.

The Home for Retarded Children is directed by E. Paul Benoit, Ph.D., formerly Coordinator of Research at Partridge School and a nationally known authority on mental retardation. The medical staff, all voluntary, is made up of approximately 25 physicians and 20 dentists, representing all specialities. The program is designed to provide complete medical and dental care for the children. The private or referring physician will be encouraged to follow his patient while in residence; any problem arising will be discussed with the private physician.

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1. The Composition of Milks, Publication 254, National Academy of Sciences and National Research Council, Revised 1953. 2. Brown, G. W.; Tuholski, J. M.; Sauer, L. W.; Minsk, L. D., and Rosenstern, I.: J. Pediat. *56*:391 (Mar.) 1960.

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